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Upper and lower bounds for the ion escape rate from Mars

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The upper and lower bounds for the total ion escape rate from Mars for different solar wind conditions are important information when we consider the loss of atmospheric ions in the total history of Mars during which the solar wind pressure may have varied by many orders of magnitude.

The ion escape rate integrated over the upper atmosphere of Mars is theoretically limited in several ways. First of all, it cannot exceed the total ion production rate in the planetary ionosphere. Actually, the total escape rate is the total ion production rate minus the total chemical loss rate integrated over the whole ionosphere. Therefore, in order to estimate the upper and lower limits of the total escape rates, we should estimate the total loss rates first. In this context, the following two points should be considered.

(1) Chemical loss rates integrated over the dayside ionosphere are a strong function of the solar wind pressure (Jin, 2006). When the solar wind pressure is high, ions produced in the upper ionosphere are convected down towards the planet, and they are chemically lost in the lower ionosphere. On the other hand, when the solar wind pressure is low, the produced ions may radially flow out by a mechanism similar to the one that produces the polar wind on the Earth.

(2) On the other hand, some of the ions produced on the dayside are convected horizontally towards the nightside ionosphere and are chemically lost there. This convection is also a function of the solar wind pressure.

(3) The chemical loss rate in the nightside ionosphere depends not only on the day-to-night convection but also on the downward convection that locally occurs in the nightside ionosphere. When the solar wind pressure is low, part of the ions that have escaped from the dayside ionosphere turn downward and are chemically absorbed in the nightside ionosphere.

With the aid of numerical simulations, we discuss the upper and lower limits for the ion escape rate for the cases of extremely high and low solar wind pressure conditions. We will discuss the result from the context of the total ion loss rate during the history of Mars.